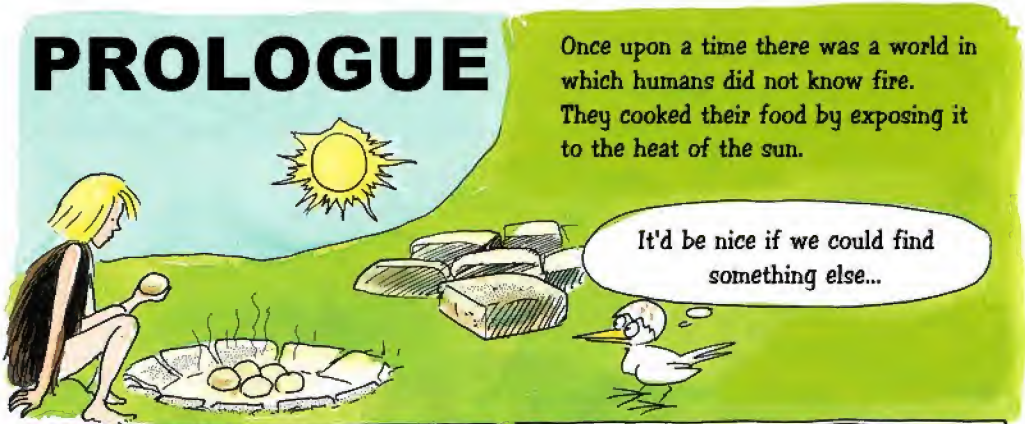
ANSELME LANTURLU

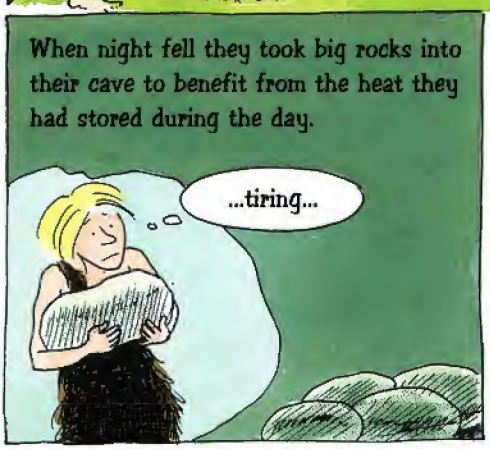
Yours Energetically

by Jean-Pierre Petit

Translated by John Murphy

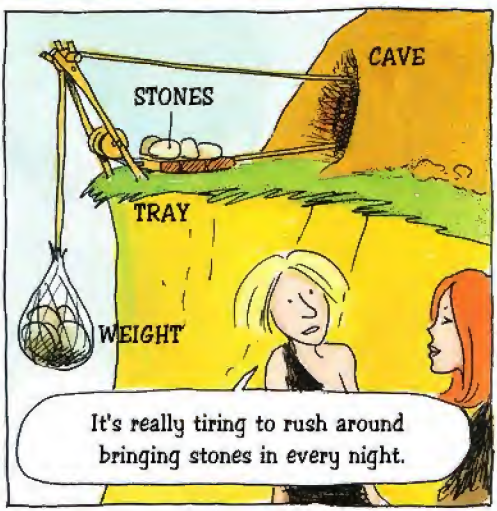
PROLOGUE

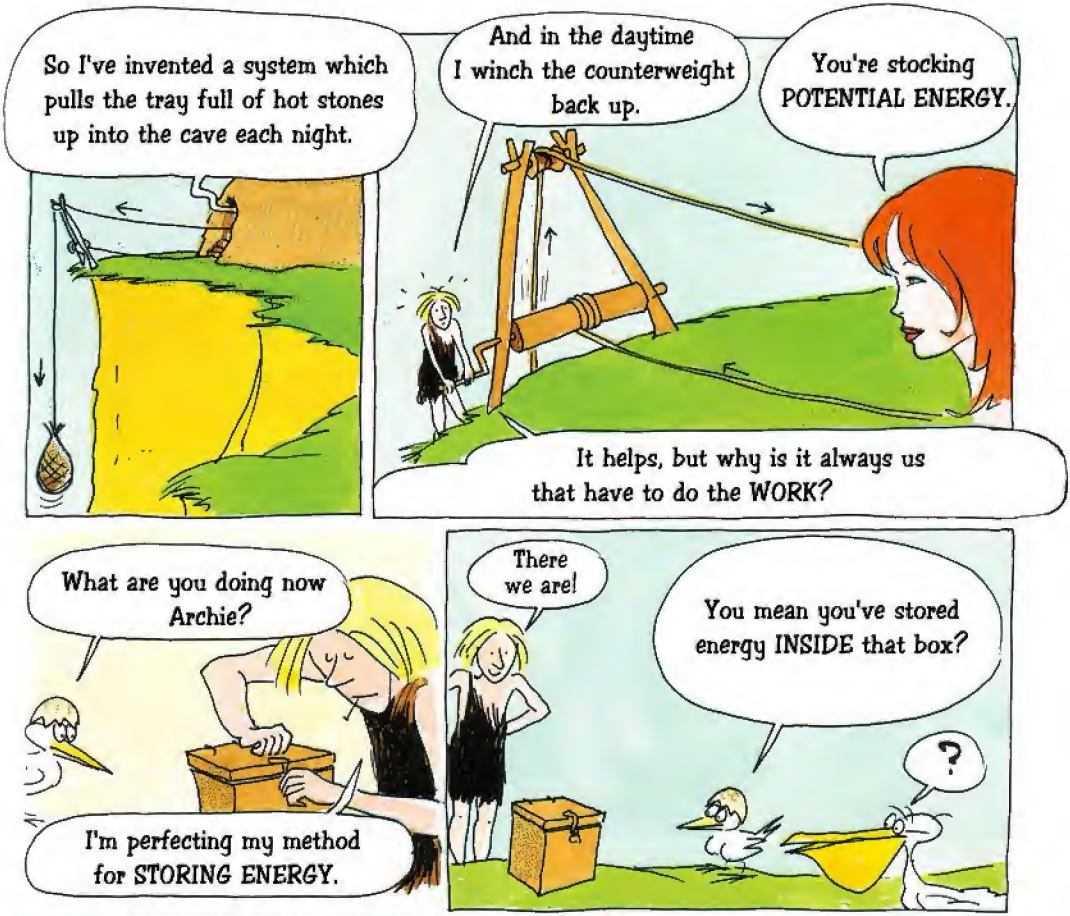

Once upon a time there was a world in which humans did not know fire. They cooked their food by exposing it to the heat of the sun.
It'd be nice if we could find something else...


When night fell they took big rocks into their cave to benefit from the heat they had stored during the day.
...tiring...


Are you asleep?
No, the stones are already cold.
We're freezing...
When winter comes it'll be worse. Half the tribe has already got a cold.

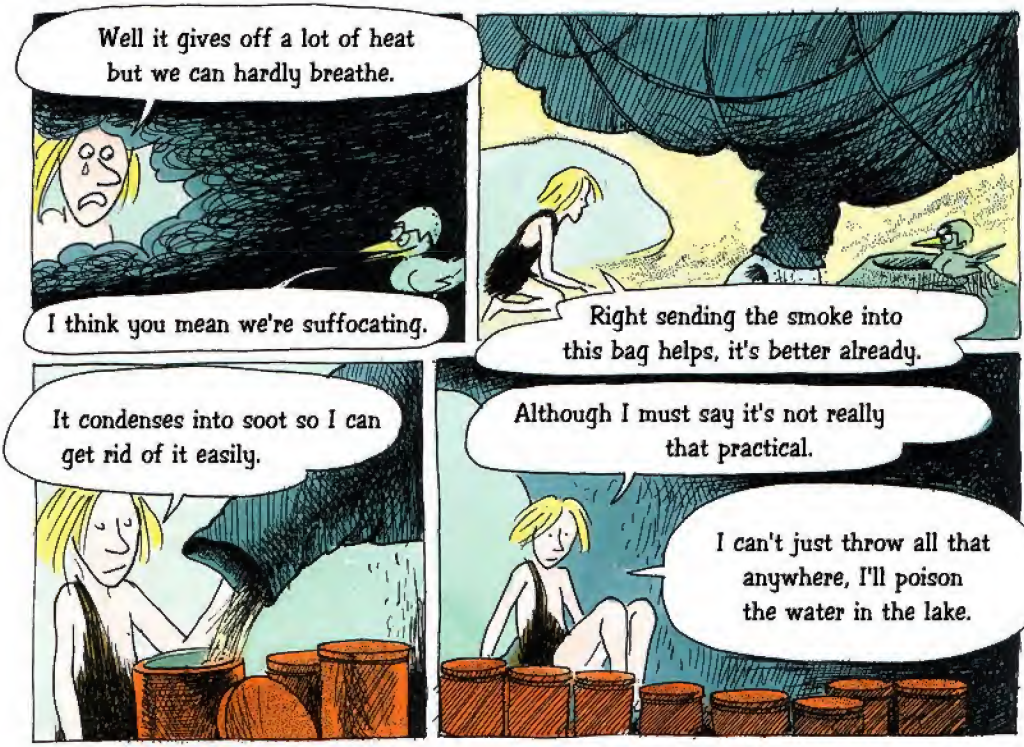

What are you doing?
I'm looking for a way of STORING ENERGY.


CAVE
STONES
TRAY
WEIGHT
It's really tiring to rush around bringing stones in every night.

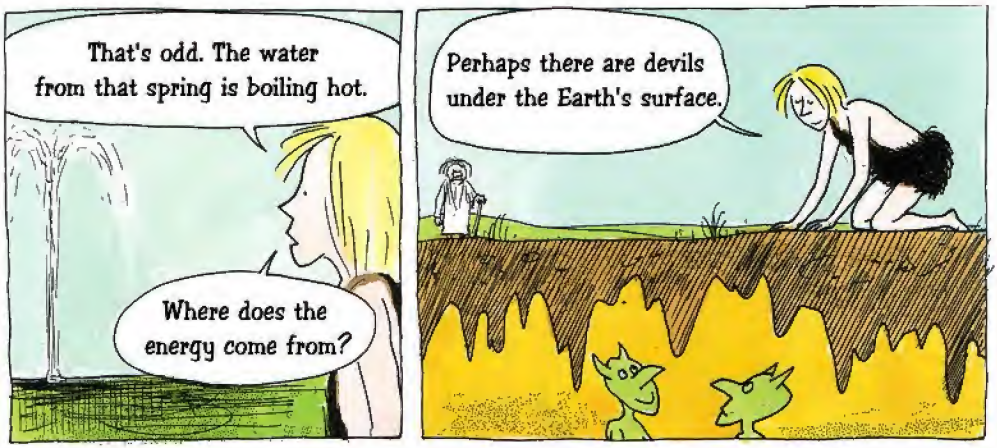

So I've invented a system which pulls the tray full of hot stones up into the cave each night.
And in the daytime I winch the counterweight back up.
You're stocking POTENTIAL ENERGY.
It helps, but why is it always us that have to do the WORK?
What are you doing now Archie?
I'm perfecting my method for STORING ENERGY.
There we are!
You mean you've stored energy INSIDE that box?
?
The system that I've designed represents a storing of INTERNAL ENERGY
?...
An energy that I can transport and re-use at will.
AAAAAHHH
CLAP!

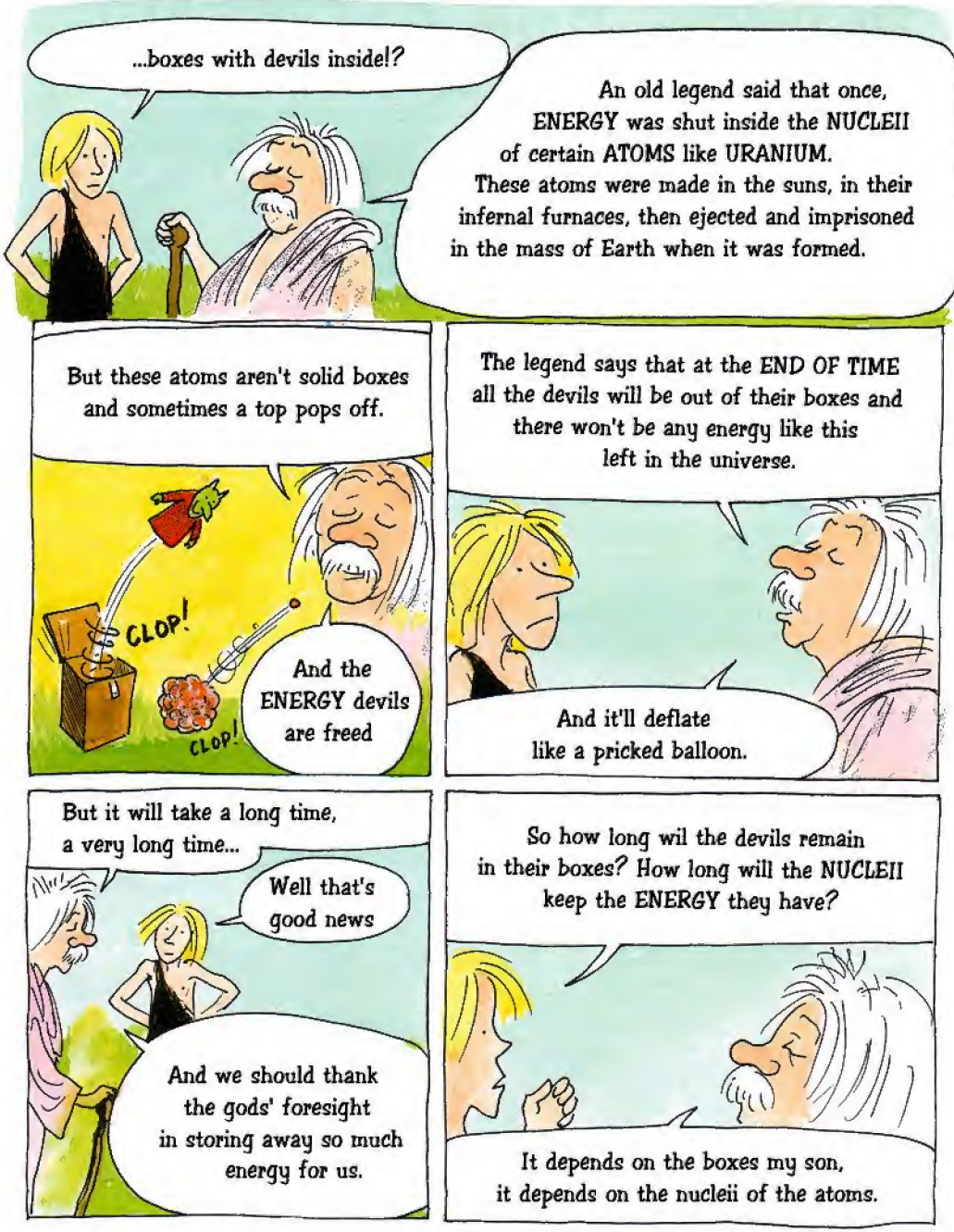
CHEMICAL ENERGY


Sophie! I've found something. There's ENERGY in this BLACK POWDER I've just invented.
We'll be able to use it to cook things and keep warm!
You'll see...
Ok, but if you want my opinion, it isn't very easy to use.
Should I forget it?
What if we mixed the powder with sand?
That works!!! The sand calms the mixture so that it frees energy more slowly!
The release of heat can be controlled.
We won't be freezing cold this winter.



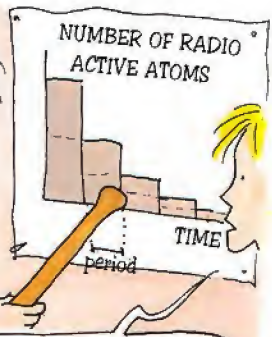
NUCLEAR ENERGY




...boxes with devils inside!?
An old legend said that once, ENERGY was shut inside the NUCLEII of certain ATOMS like URANIUM. These atoms were made in the suns, in their infernal furnaces, then ejected and imprisoned in the mass of Earth when it was formed.
But these atoms aren't solid boxes and sometimes a top pops off.
CLOP!
CLOP!
And the ENERGY devils are freed
The legend says that at the END OF TIME all the devils will be out of their boxes and there won't be any energy like this left in the universe.
And it'll deflate like a pricked balloon.
But it will take a long time, a very long time...
Well that's good news
And we should thank the gods' foresight in storing away so much energy for us.
So how long wil the devils remain in their boxes? How long will the NUCLEII keep the ENERGY they have?
It depends on the boxes my son, it depends on the nucleii of the atoms.

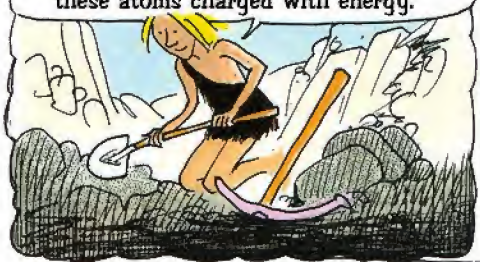
RADIOACTIVE PERIOD OF AN ELEMENT

If we take an ensemble of boxes with devils in them, after a time T, called HALF-LIFE, or PERIOD, half of the devils will have been freed. In an identical lapse of time, half the remaing boxes will open in their turn, and so on. This half-life can vary greatly, from hundreds of thousands of years to a fraction of a second.



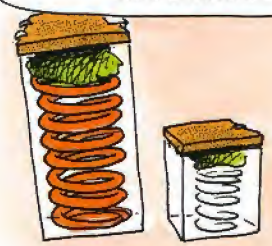
And if there weren't all these boxes with their devils, all these nucleii filled with energy inside the Earth then we'd be much colder in winter.

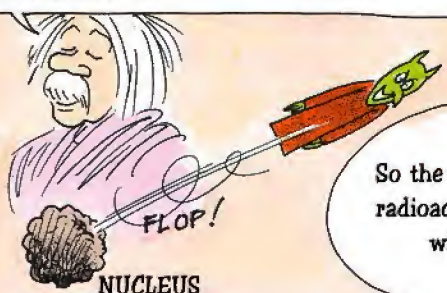
It would be nice if I could find all these atoms charged with energy.



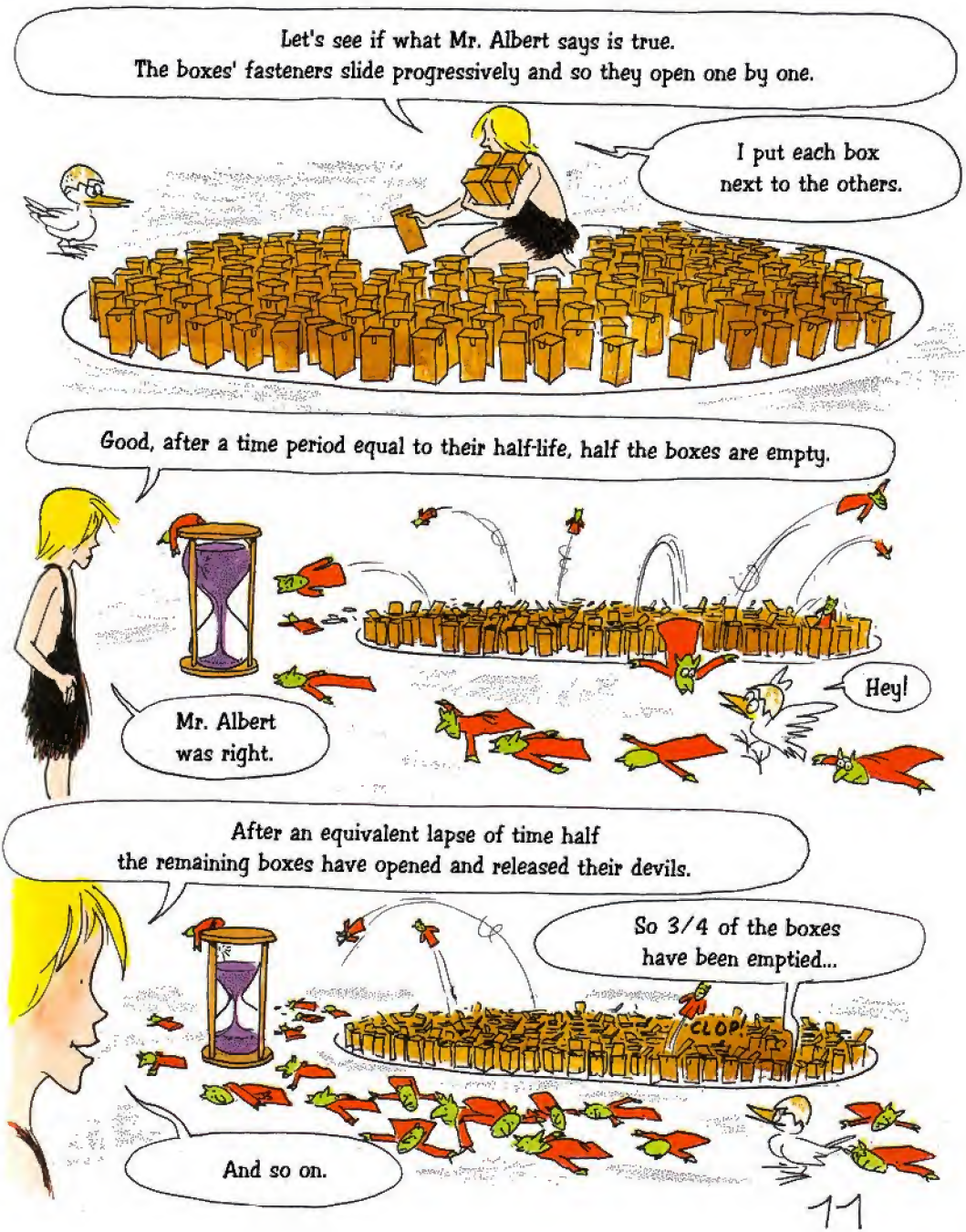
If I could put enough of them into a bottle I could keep warm all winter.

Careful Archibald, the NUCLEAR ENERGY springs are much more powerful than CHEMICAL ENERGY, HUNDREDS OF THOUSANDS TIMES MORE POWERFUL.





So the devils emitted by the radioactive nucleii shoot out with great violence.


Let's see if what Mr. Albert says is true.
The boxes' fasteners slide progressively and so they open one by one.
I put each box next to the others.
Good, after a time period equal to their half-life, half the boxes are empty.
Mr. Albert was right.
Hey!
After an equivalent lapse of time half the remaining boxes have opened and released their devils.
So 3/4 of the boxes have been emptied...
CLOP!
And so on.

So that means that it slows with time, the rhythm of boxes opening tends to diminish.

The Earth must have been a lot more radioactive in the beginning.

And then it calmed down.

CONVERSION OF ENERGY

But where's the HEAT in all that?

What if we put it in a cooking pot?

Let's try...

It works. The ENERGY emitted by the RADIOACTIVE ATOMS is absorbed by the water and CONVERTED INTO HEAT.

Yes but this NATURAL RADIOACTIVITY doesn't release much ENERGY.

So we'd need a lot of radioactive material to be able to keep ourselves warm.

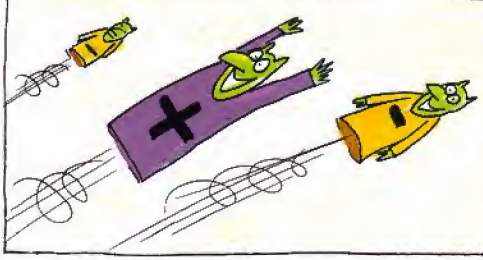
THE DIFFERENT SPECIES OF DEVILS

Basically there is only one devil species. The first things that nucleii can emit are X or Y RADIATION. A sort of invisible light.

Mind your backs!!

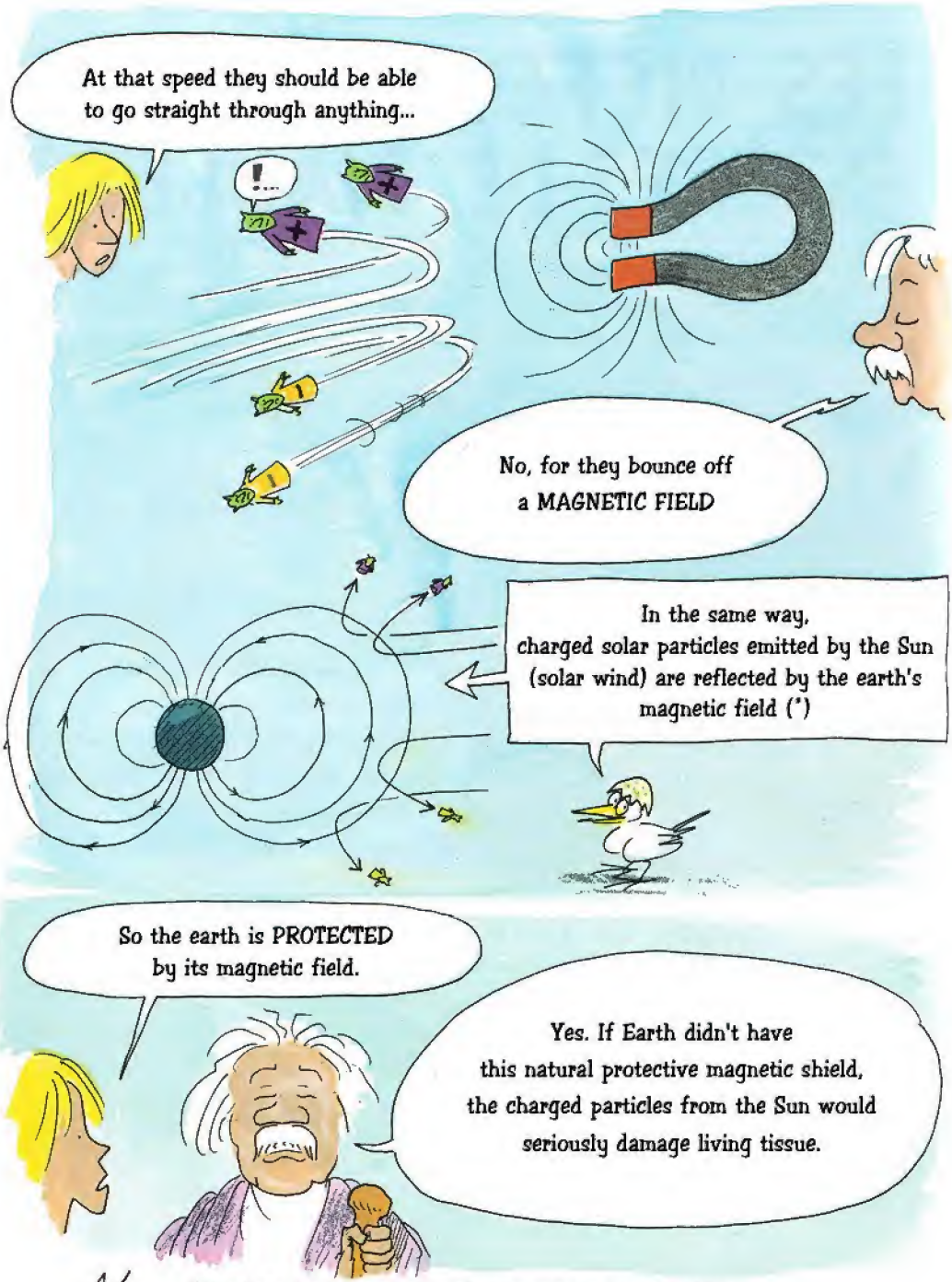
They can be absorbed with a sufficiently thick lead barrier and then their energy is converted into heat.

There are other types of devils that have an ELECTRIC CHARGE

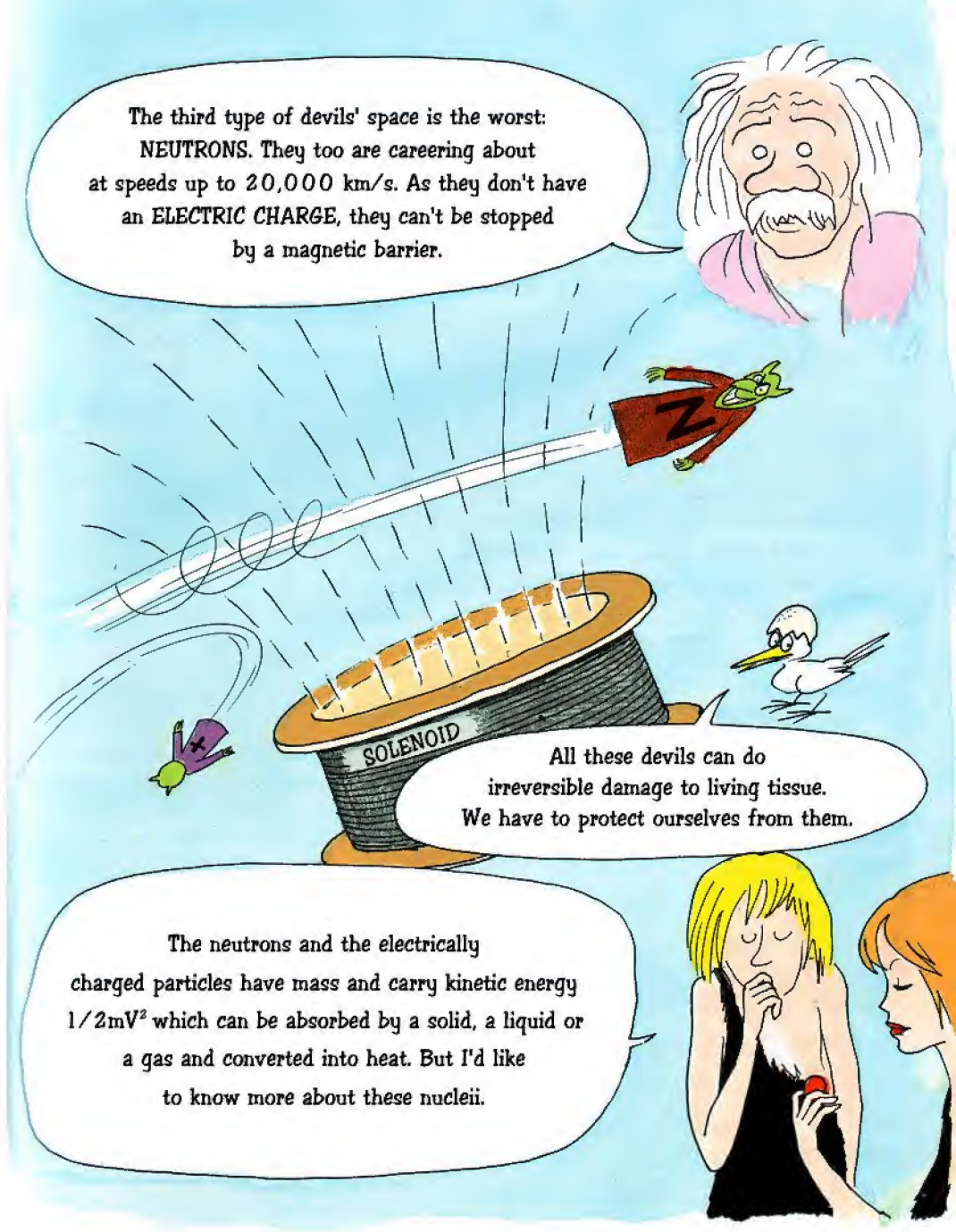


Do they go fast?

It depends on their ENERGY but they can reach speeds of several thousand kilometres a second.



(*) For Earth, the geographic and magnetic poles are in inverted positions.


The third type of devils' space is the worst: NEUTRONS. They too are careering about at speeds up to 20,000 km/s. As they don't have an ELECTRIC CHARGE, they can't be stopped by a magnetic barrier.
Z
SOLENOID
All these devils can do irreversible damage to living tissue. We have to protect ourselves from them.
The neutrons and the electrically charged particles have mass and carry kinetic energy $1/2mV^2$ which can be absorbed by a solid, a liquid or a gas and converted into heat. But I'd like to know more about these nucleii.

NUCLEUS STABILITY

To make NUCLEII you need NEUTRONS, PROTONS and particles called MESONS.

NUCLEUS

MESONS

Uranium 235
92 PROTONS
+ 143 NEUTRONS
= 235 NUCLEONS

Plutonium 239
94 PROTONS
+ 145 NEUTRONS
= 239 NUCLEONS

MESONS in the NUCLEII act a bit like ELECTRONS in MOLECULES: they ensure COHESION.

Electron ensuring A MOLECULAR LIAISON.

So NUCLEII are MOLECULES?

Helium (Nucleus)

Ammonia (molecule)

NUCLEII are an assembly of NUCLEONS. MOLECULES are an assembly of NUCLEII. And, in fact, we are assemblies of molecules.

CHEMISTRY interprets the rearrangement of MOLECULES.

molecules

OXYGEN PLUS HYDROGEN → WATER

NUCLEAR PHYSICS studies the REARRANGEMENT of NUCLEII

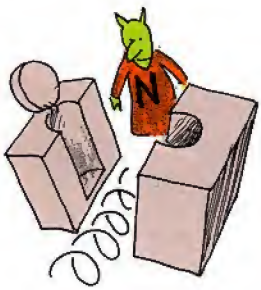
A nucleus that is considered to be UNSTABLE is a nucleus with a short life

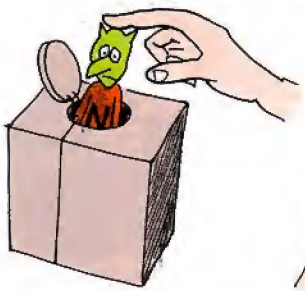
But neutrons, when acting on certain nucleii (themselves relatively stable having very long lives) can destabilise them completely and cause them to split, FISSION.

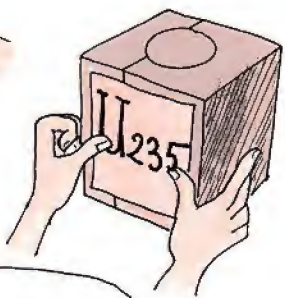
That's the case for URANIUM 235 and PLUTONIUM 239

FISSION

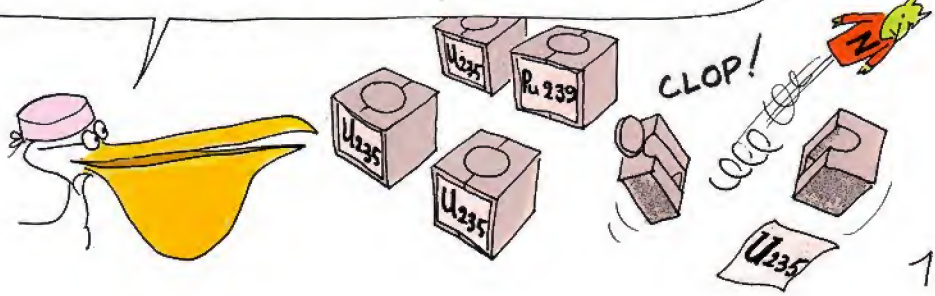
These nucleii can be represented as an assembly of two blocks of different masses and with one neutron.







Uranium 235 and Plutonium 239 nucleii have a certain type of natural radioactivity, associated with a very long period.



Here's a FISSION reaction.
The encounter with a neutron has destabilised the Plutonium nucleus. The result of this reaction is the re-emission of 2 neutrons (*)

CLOP!!

Pu239

Pu 239

I'm going to study that closely.

Archie has assembled lots of devil boxes inside a circle of radius R.

Uranium 235 or Plutonium 239

Now the ENERGY devils are coming out of their boxes

CLAP!

!?!

Pu239

Here it is a question of NEUTRONS

Huh, there's a thing!

CLAP!!

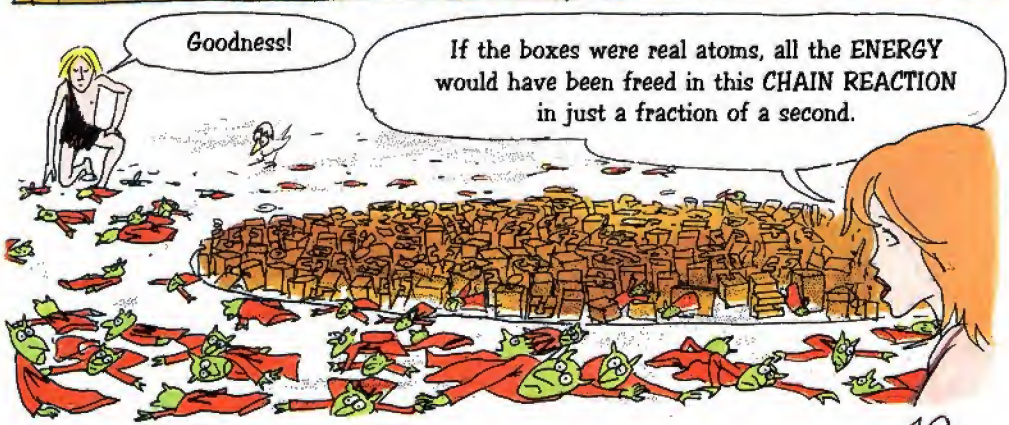
BOUM

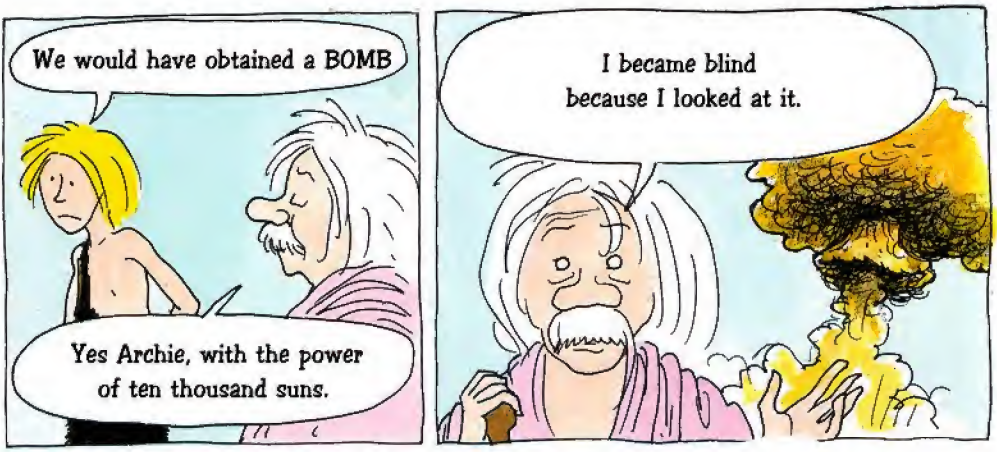
When that devil hit a nearby box it triggered its disintegration mechanism and let out the neutron-devil that was inside.

(*) This is a schematic image. In fact the incident neutron is first absorbed by the fuse nucleus (U235 becomes U236 and P239 becomes P240). These are new objects, very unstable, which break down almost immediately.

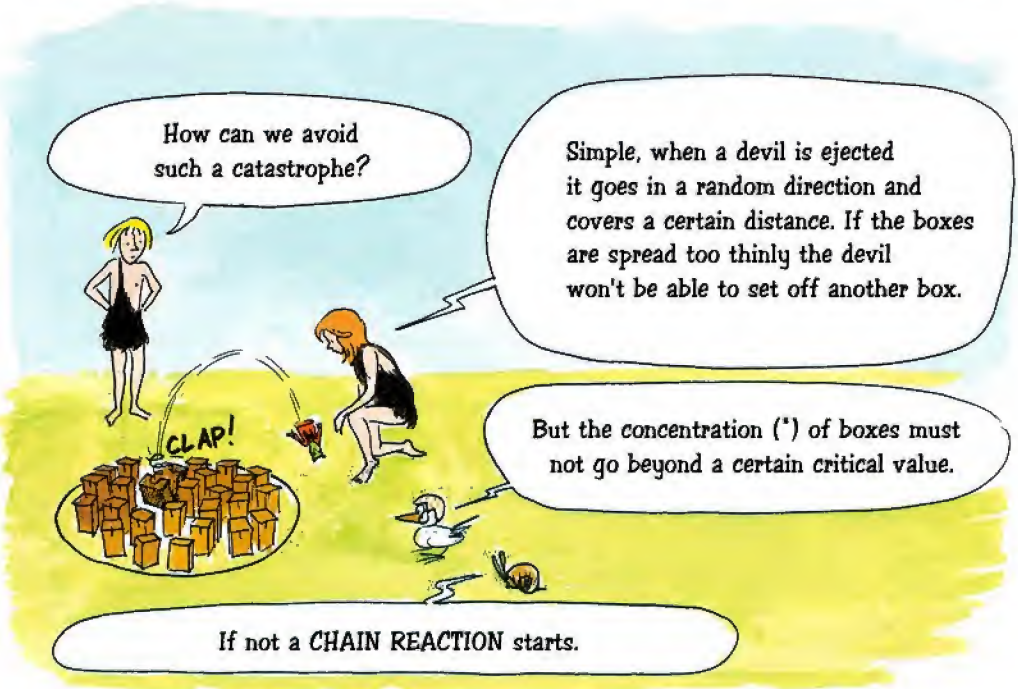
CHAIN REACTIONS

The two devils then make two more boxes open!





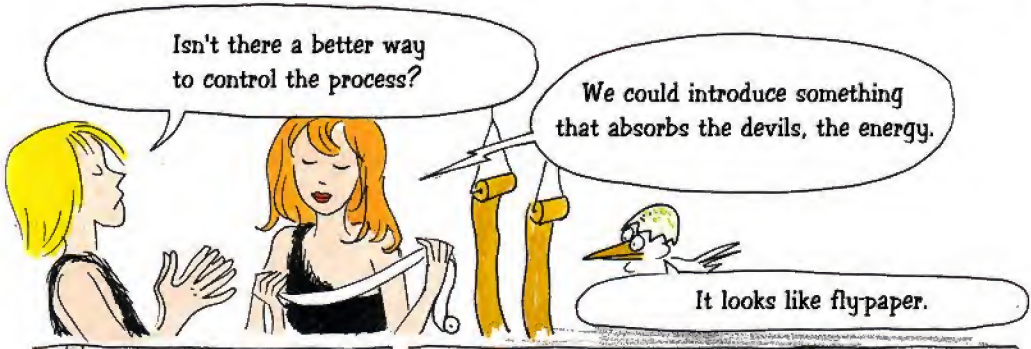
CRITICAL CONDITIONS

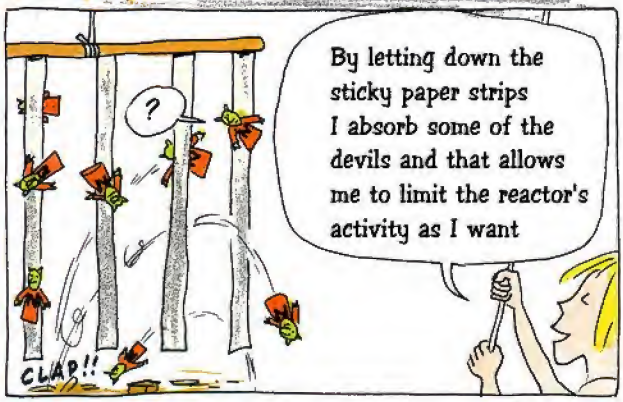


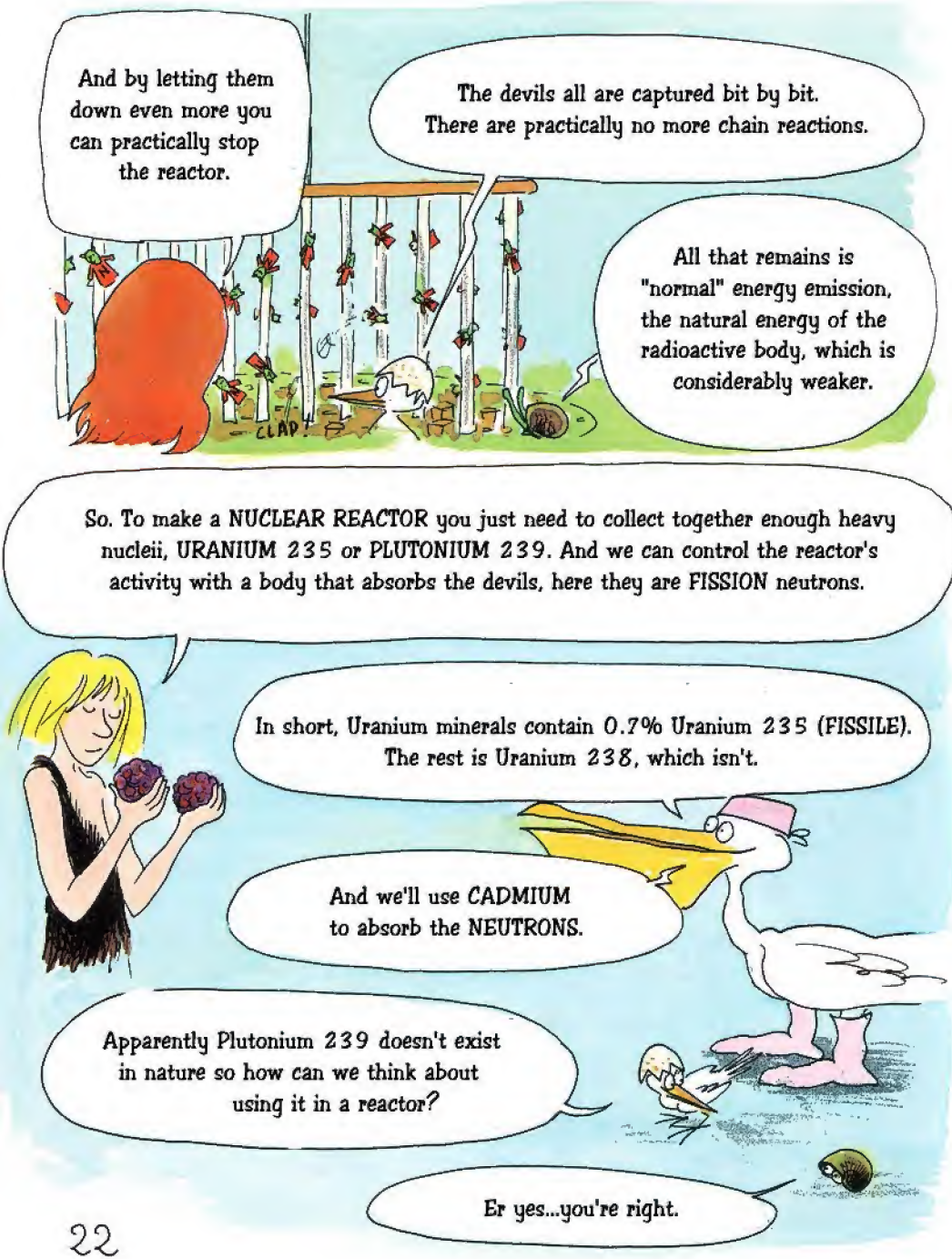
(*) Normally referred to as the CRITICAL MASS.

In fact, between the weak NATURAL RADIOACTIVITY emission level and the CHAIN REACTION, we can find an average term. By adjusting this CONCENTRATION, which is quite difficult and delicate, we can set the number of devils that will be ejected each second, that is to say the energy flow.

THE NUCLEAR REACTOR

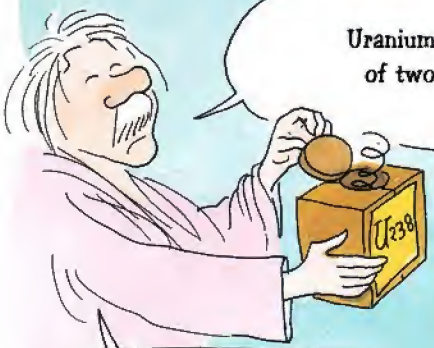


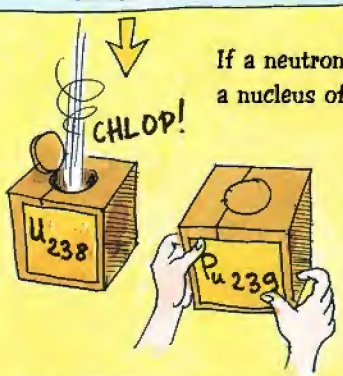



And by letting them down even more you can practically stop the reactor.
The devils all are captured bit by bit. There are practically no more chain reactions.
All that remains is "normal" energy emission, the natural energy of the radioactive body, which is considerably weaker.
CLAP!
So. To make a NUCLEAR REACTOR you just need to collect together enough heavy nucleii, URANIUM 235 or PLUTONIUM 239. And we can control the reactor's activity with a body that absorbs the devils, here they are FISSION neutrons.
In short, Uranium minerals contain 0.7% Uranium 235 (FISSILE). The rest is Uranium 238, which isn't.
And we'll use CADMIUM to absorb the NEUTRONS.
Apparently Plutonium 239 doesn't exist in nature so how can we think about using it in a reactor?
Er yes...you're right.

FERTILE MATERIAL

Uranium 238 could be considered to be an assembly of two elements. There's room left for a neutron.

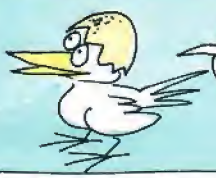




If a neutron lodges itself in a nucleus of Uranium 238

it will change into Plutonium 239 and that is FISSILE

In other words, when a Uranium reactor is operating it contains a mix of FISSILE material and FERTILE material. It converts a certain amount of the FERTILE material into FISSILE material



A certain amount? How much is that?

It depends how we operate the reactor. At first FISSION NEUTRONS are emitted in all directions, at 20,000 kilometers a second.

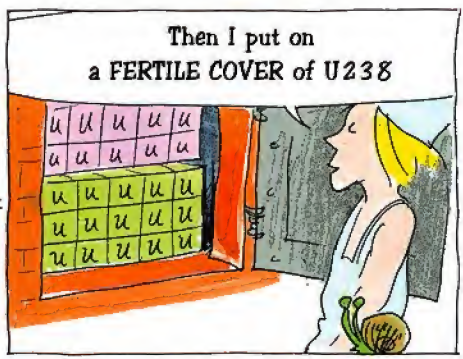
RAPID NEUTRON REACTORS

These RAPID NEUTRONS interact easily with fertile U238 thus creating Pu239 at a good rate.

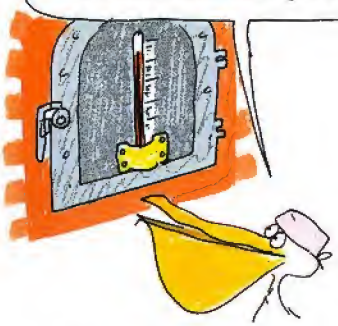
What are you doing?

I'm loading my reactor with a mineral rich in Uranium 235 (enriched Uranium)

Then I put on a FERTILE COVER of U238

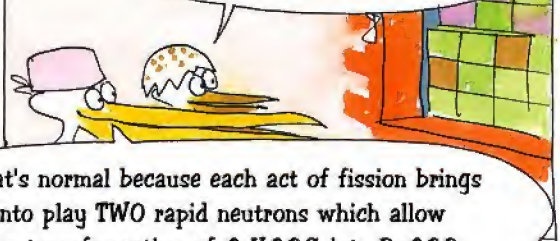


The FAST NEUTRONS move at 20,000 km/s in the HEART of the REACTOR. If we thought of them as gas molecules they would be at a temperature of 16 thousand million degrees.



THREE YEARS LATER

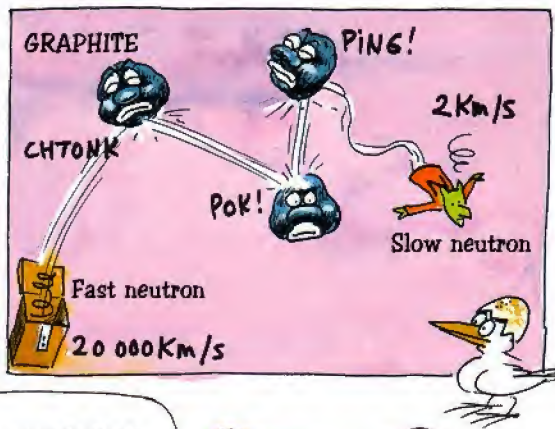
Oh! Archie has made MORE Pu239 than he has used U235, It's a SUPERGENERATOR



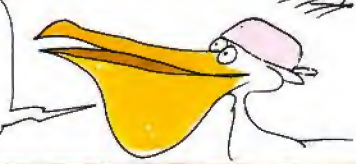
That's normal because each act of fission brings into play TWO rapid neutrons which allow the transformation of 2 U238 into Pu239

SLOW NEUTRON REACTORS

With CADMIUM I can absorb neutrons and so easily control the reactor's activity (or even stop it). But with GRAPHITE and HEAVY WATER I can SLOW the neutrons without absorbing them. These are called MODERATORS



In this way we can lower the THERMAL AGITATION SPEED of the neutorns to 2 Km/s. This neutron gas, cold, is at the general temperature of the reactor.



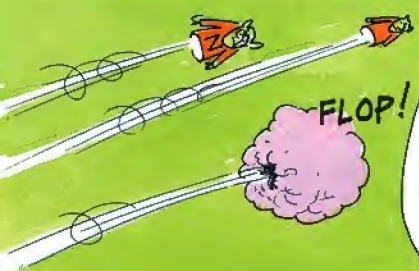
A little Pu 239 is still made but a lot less than in a rapid neutron reactor

There is no clear frontier between the two types of reactor. There are also 'warm' reactors, half way between the two.

RADIOACTIVE WASTE INDUCED RADIOACTIVITY

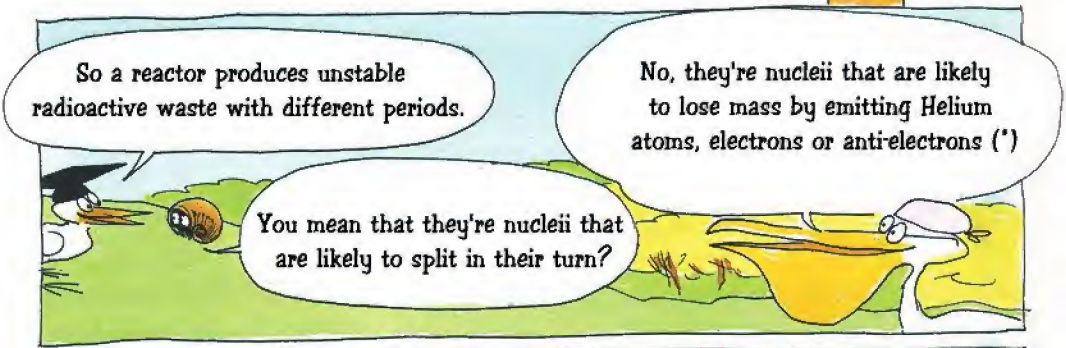
The U235 and Pu239 nucleii break into two pieces in many different ways. Here the example is of Uranium 235 being split into radioactive Strontium 94 and Xenon 140. Note that 94+140+1=235

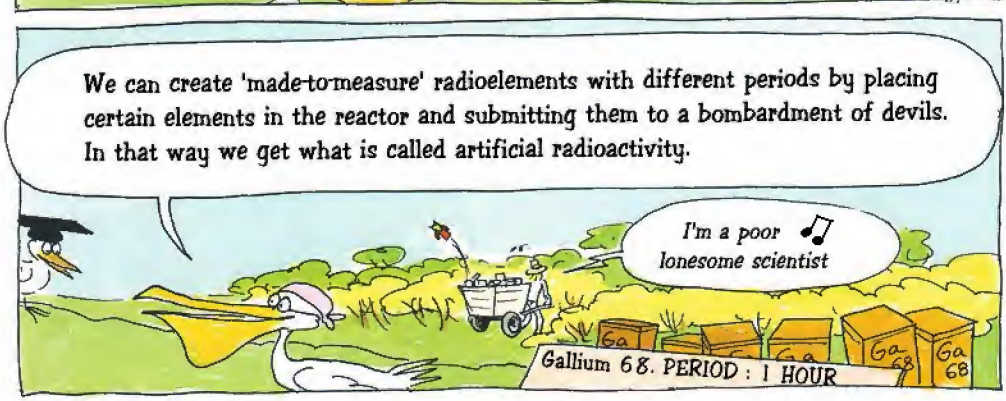
All that is a bit of a nuisance. Many FISSION BY-PRODUCTS have a long life and remain radioactive for a very long time. STRONTIUM can fix itself in bone material and IODINE in the Thyroid. Plutonium is also very dangerous, it can provoke CANCERS and LEUKEMIA



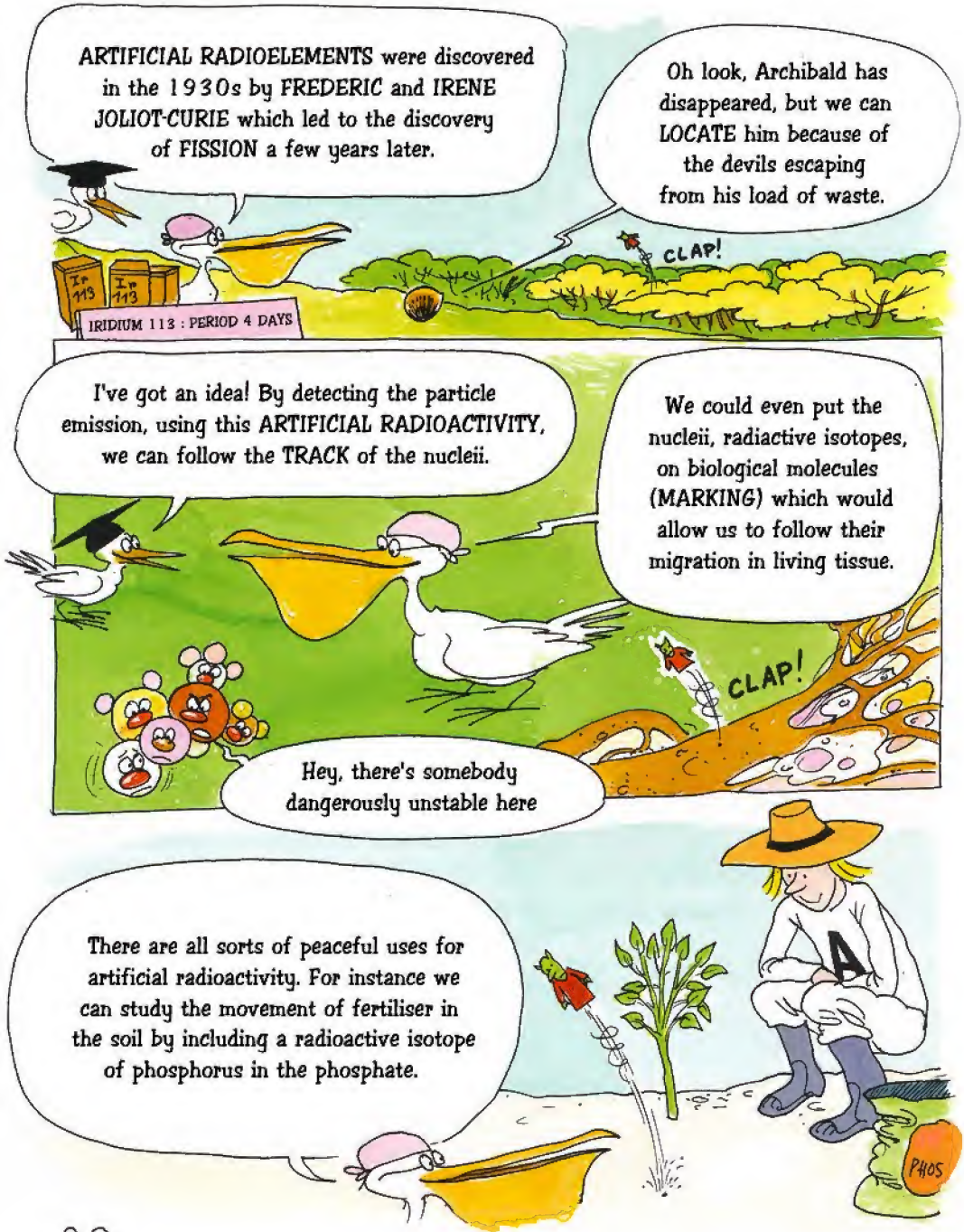
Fission neutrons can also be absorbed by peaceful atoms, such as those forming the structure of the reactor, which can make them dangerous and unstable as well as radioactive, so increasing the amount of radiactive waste.

MADE-TO-MEASURE RADIOELEMENTS





(*) "Alpha" or "Beta" radioactivity.


ARTIFICIAL RADIOELEMENTS were discovered in the 1930s by FREDERIC and IRENE JOLIOT-CURIE which led to the discovery of FISSION a few years later.
Oh look, Archibald has disappeared, but we can LOCATE him because of the devils escaping from his load of waste.
CLAP!
Ir 113
Ir 113
IRIDIUM 113 : PERIOD 4 DAYS
I've got an idea! By detecting the particle emission, using this ARTIFICIAL RADIOACTIVITY, we can follow the TRACK of the nucleii.
We could even put the nucleii, radiactive isotopes, on biological molecules (MARKING) which would allow us to follow their migration in living tissue.
CLAP!
Hey, there's somebody dangerously unstable here
There are all sorts of peaceful uses for artificial radioactivity. For instance we can study the movement of fertiliser in the soil by including a radioactive isotope of phosphorus in the phosphate.
A
PHOS

A-BOMBS

Nuclear physics has allowed considerable progress to be made in fireworks science. In suddenly bringing together two masses of fissile material (U235 and Pu239) with the help of an explosive, we create critical conditions and provoke an intense chain reaction, with undeniable aesthetic effects.

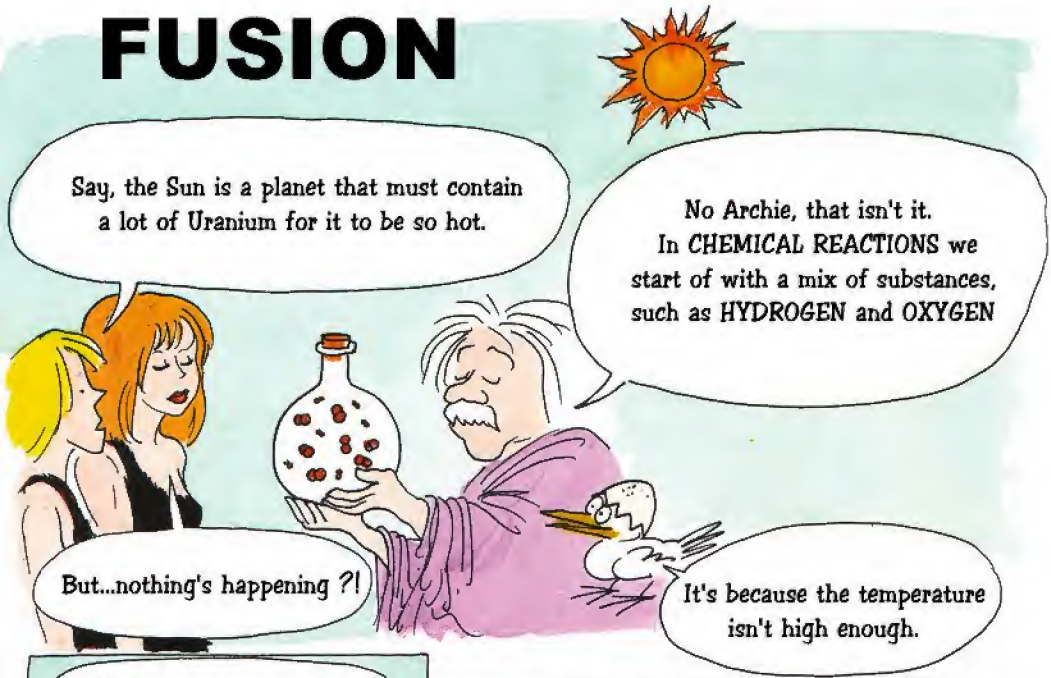
Let's see. By bringing together these two masses I obtain a CRITICAL MASS

A great number of all sorts of devils are emitted and the radioactive waste rises into the upper atmosphere by ascendance which is caused by the release of intense heat. But that's nice because the neighbours can benefit too

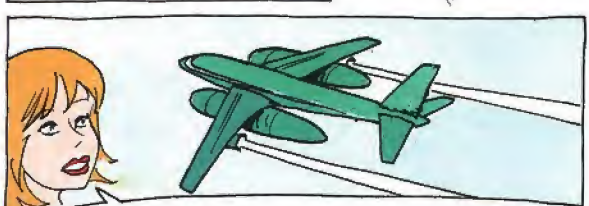
If you want to join the HAPPY PYROTECHNICIANS you'll need a pure fissile material (100% U235 or Pu239). There are two ways to do it, either refine natural Uranium or apply to your neighbourhood reactor to collect the Pu239 that is produced after each cycle of operation.

It's coming, it's coming !..

FUSION



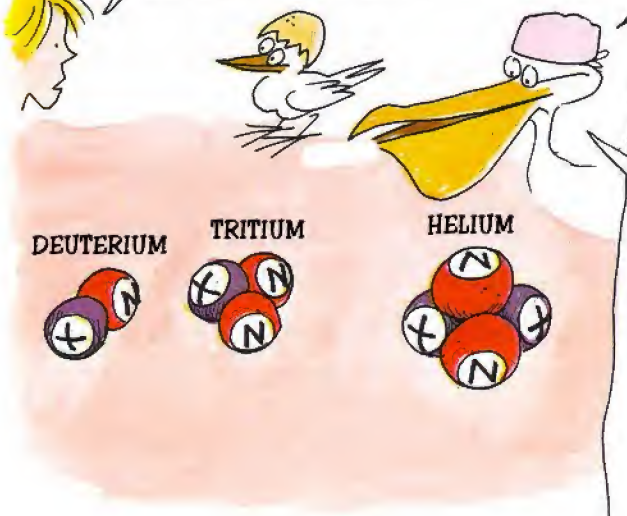
So there are lots of reactions that give off a great deal of energy without producing toxic substances.



If one day we use flying planes with a hydrogen-oxygen mix (stored in liquid form) all they'd leave behind as they passed would be clouds!

Maybe we could also "burn" the nucleii mixtures.

Yes, if we brought their temperature up high enough



We could make DEUTERIUM react with TRITIUM, which are two sorts of HEAVY HYDROGEN (the hydrogen nucleus is light, constituted of a single proton P). The nucleii of these ISOTOPES are only differentiated by the number of neutrons they have.
The mix od Deuterium and Tritium tends to give Helium

Here's an element of the gas HEAVY HYDROGEN, half DEUTERIUM, half TRITIUM. At normal temperature the ELECTRONS turn around the nucleii and ensure molecular liaison (by linking the nucleii two by two)

Deuterium molecule

Tritium molecule

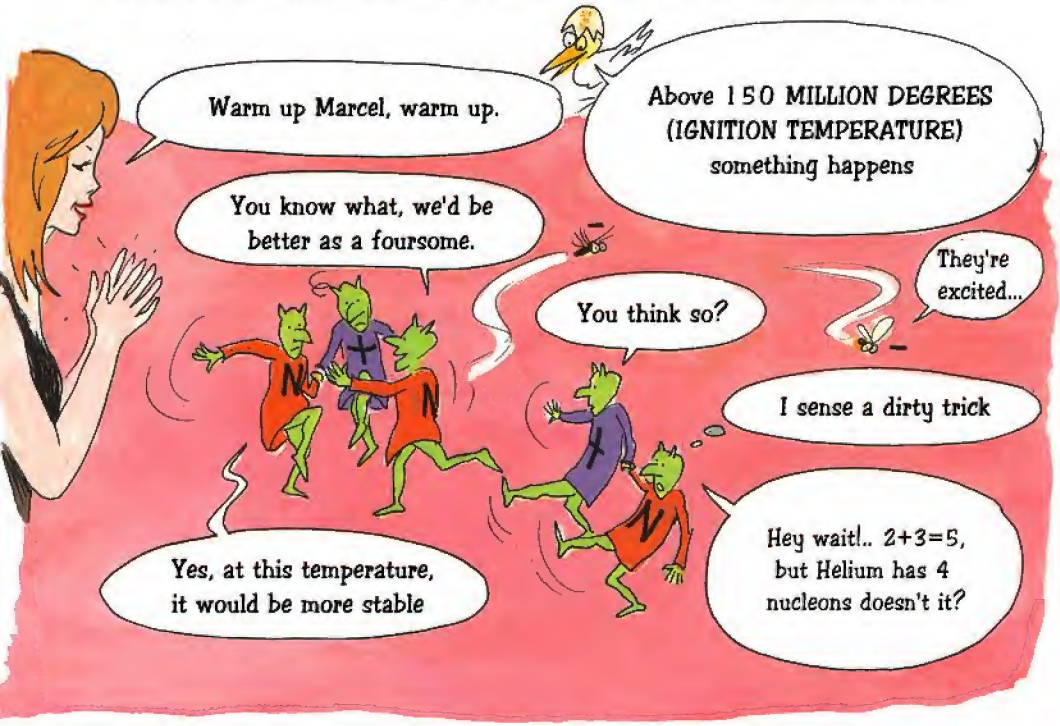
Then the dance rhythm becomes really devilish. Molecules break up (disassociation) and the electron-bees orbit around a single nucleus.

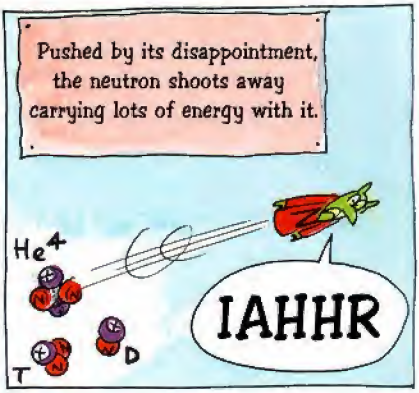
APPROACHING THREE THOUSAND DEGREES

There's no way we can orbit around these nucelii, they're always moving.

Yep, it's becoming infernal. I give up...

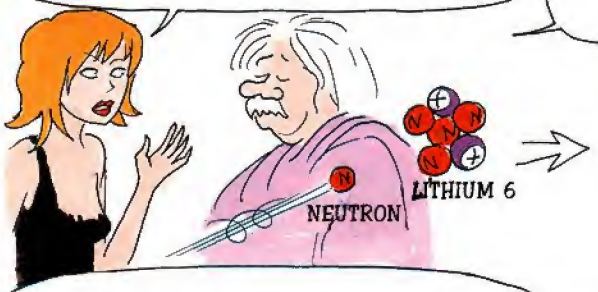
The hot gas then becomes a soup of nucleii and free electrons, a HOT PLASMA.





In this case, FUSION is just as polluting as FISSION because these fusion neutrons will transform the nearby atoms, turning them into radioactive atoms.

So we try to absorb these neutrons with Lithium 6, which gives Helium 4 and Tritium 3.



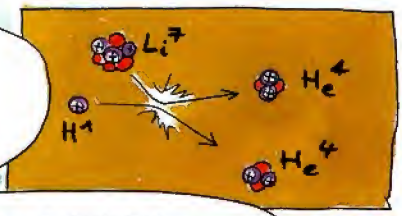
In other words, the envelope of Lithium 6 behaves as a "fertile" material. This reaction is supposed to give "fusion fuel", Tritium 3.

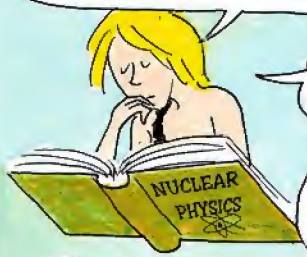
Yes, a fusion reactor is related to a supergenerator. Luckily, because Tritium 3 is unstable (*) and doesn't exist in a natural state.

But only Tritium is regenerated.

(*) Its half-life is only 12 years.

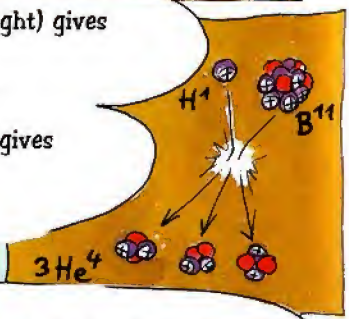
Nevertheless, I see that there are all sorts of fusion reactions and nucleii rearrangements which don't release free neutrons.





Lithium 7 + Hydrogen 1 (light) gives 2 Helium 4
(7 + 1 = 2 x 4)

Boron 11 + Hydrogen 1 gives 3 Helium 4
(11 + 1 = 3 x 4)



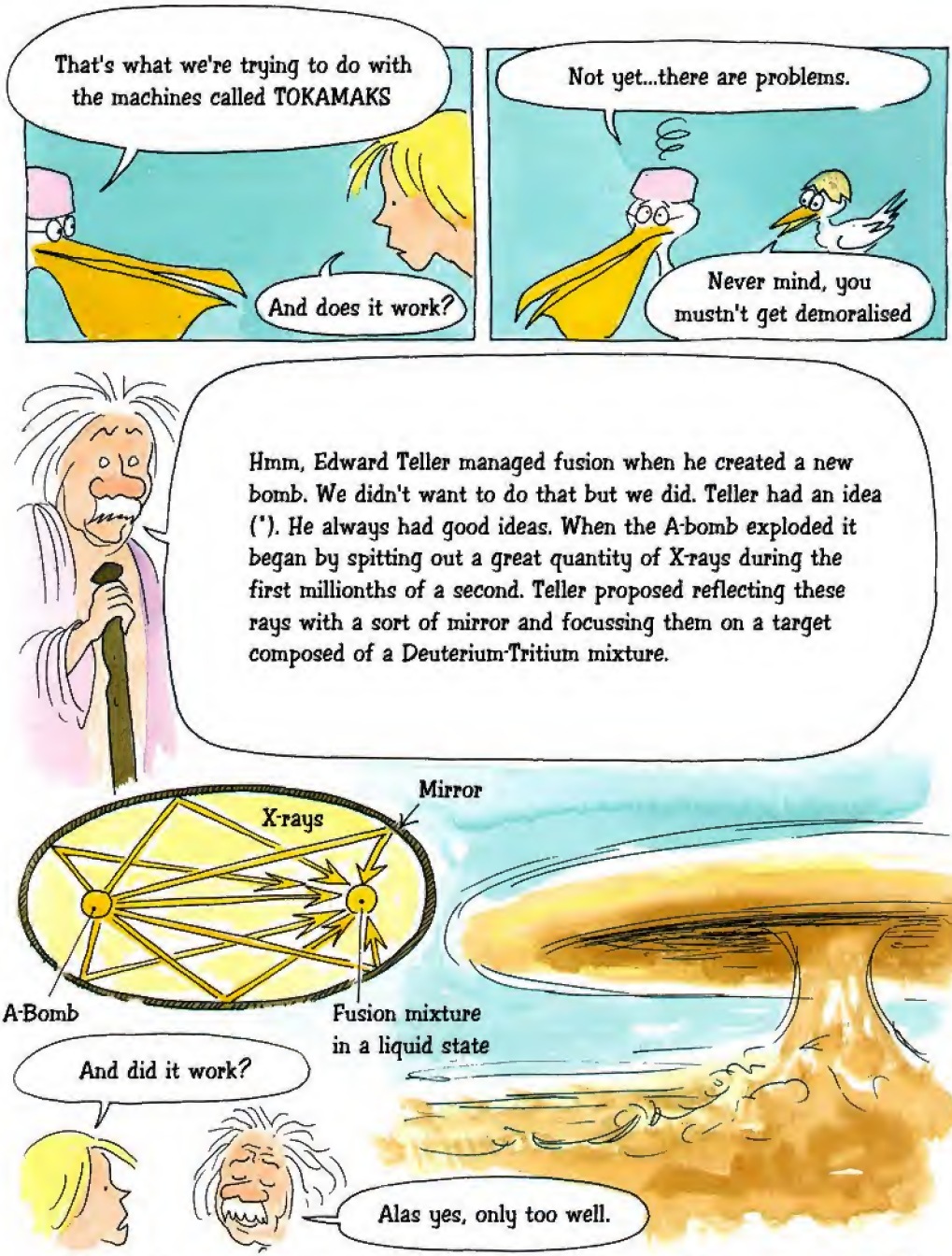
The first has an ignition temperature of 500 million degrees and, for the second, close on a thousand million degrees!..

Hmm...obviously...but exactly how do we fuse these nucleii?

In the heart of the sun it happens slowly but at a temperature that is only 15 million degrees.

So the sun is just like embers then?

Yes, to get a nuclear "fire" you need 150 million degrees for reactions to take place in, let's say, a period of time of the order of a second.



(*) Edward teller, researcher at Los Alamos during the war, was the model for Doctor Strangelove in the film 'How I stopped worrying and learned to love the bomb'.

Teller even built a mirror of Uranium 238

Why Uranium 238?

But of course, think about it. The H-bomb exploded. Neutrons from fusion attacked the FERTILE U238 material and transfromed it into Pu239 which fissioned immediately

That was the terrible FISSION-FUSION-FISSION bomb

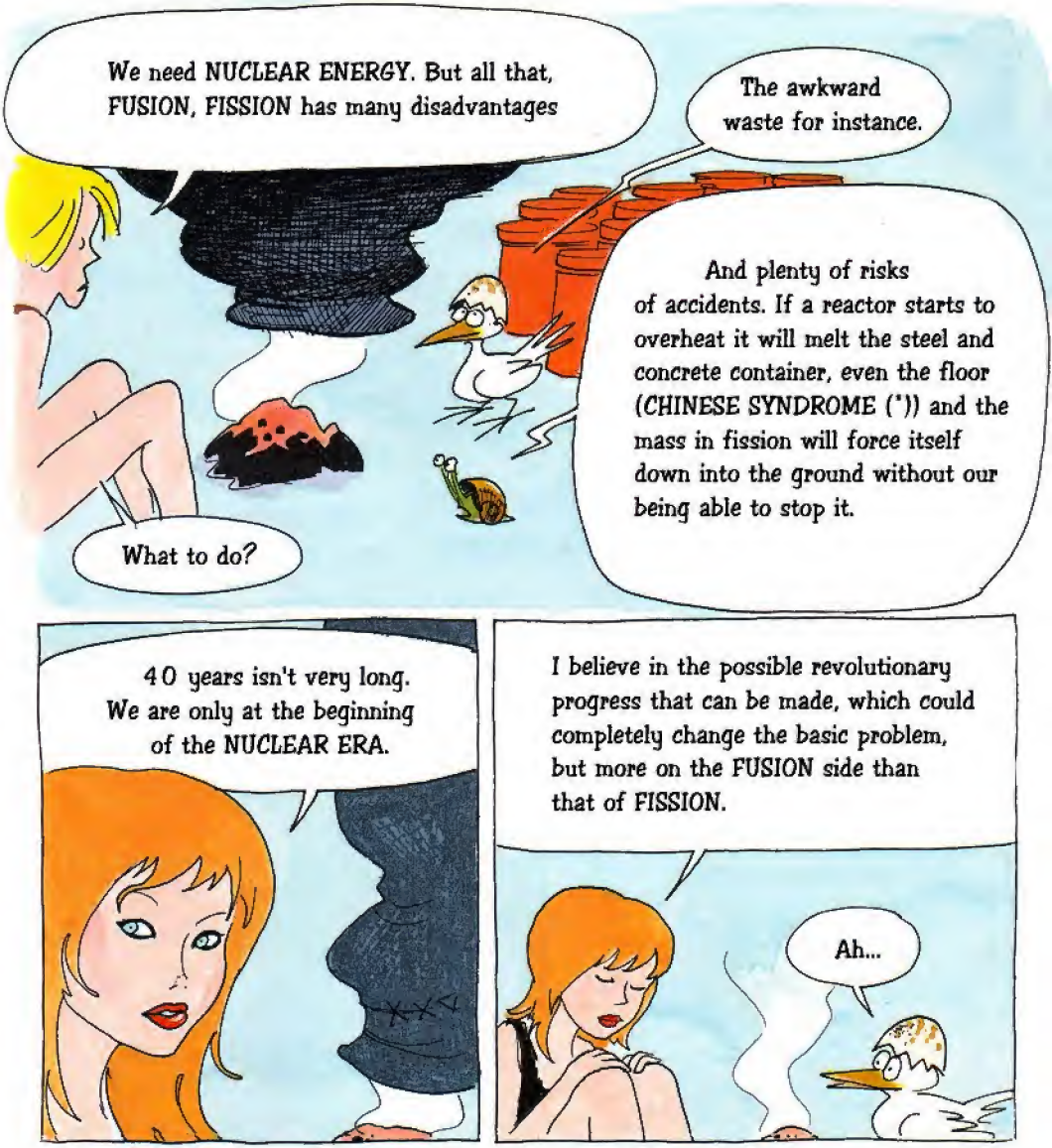
FUSION BY DIRECTED ENERGY

Yep, I'm getting a tan.

An attempt was made to create FUSION by localising onto a DEUTÉRIUM-TRITIUM mixture (in liquid state) all the energy forms: radiations, emitted by powerful LASERS, various particles: electrons, nucleii from accelerators. The POWER needed is phenomenal. To set off this THERMONUCLEAR fire, an energy equivalent to that of a solar mirror the size of France needs to be concentrated (for a few thousand millionths of a second) on a sphere of 1 mm diameter

The INSTANT POWER is enormous but the global ENERGY remains modest: this nuclear "match" is equivalent to two hundred grams of powder.

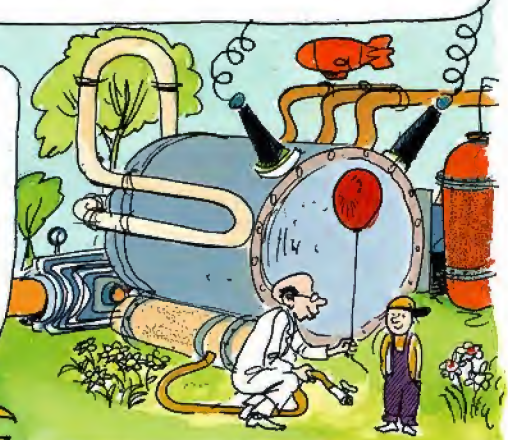
EPILOGUE



(*) An image due to atomists, according to whom the reactor going through the Earth from one side to the other would reappear in... China!...

Theoretically, in fusion reactions, where free neutrons don't intervene, we could CONFINE the FUSION PLASMAS by using powerful magnetic equipment (charged particlesd "run away" from regions with intense magnetic fields).

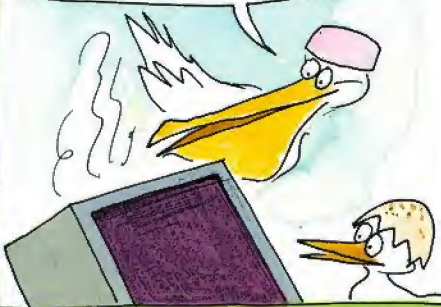
THE GOLDEN AGE!
The fusion generating station, non-polluting (lithium-hydrogen or boron-hydrogen). The only product of the reaction is helium which we could use to inflate balloons.



Don't make me laugh, it's a dream!

Nevertheless, catalytic stoves exist that allow heat to be produced AT HOME with the windows closed and without using a chimney.

It's true, it creates water vapour and carbon dioxide which can be breathed in in moderate quantities.



Could a FUSION CATALYSER exist that would allow operation at a suitably low temperature?

We already know one: Carbon

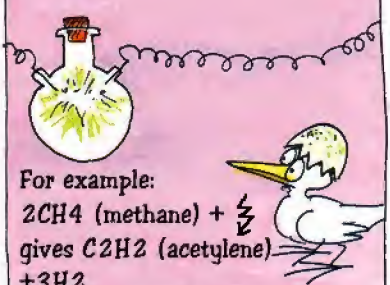
Ah yes, in fact, how does the Sun manage to work by fusion when its central boiler is at 15 MILLION DEGREES, that is to say at a temperature TEN TIMES LESS THAN THE IGNITION TEMPERATURE which is 150 MILLION DEGREES?

The Carbon serves as a catalyst. It intervenes in the stages, fairly complex ones, of the reaction and, in the end, is regenerated. It begins with Carbon 12 then Hydrogen 1 giving Nitrogen 13. Then the Nitrogen 13 is transformed into Nitrogen 15 and finally: Nitrogen 15 + Hydrogen 1 -> Carbon 12 + Helium 4 (Bethe's cycle).

But this reaction is far too SLOW (except for the Sun, which has plenty of time).

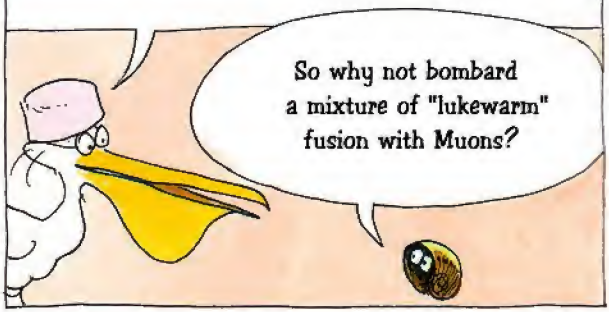
MUONS

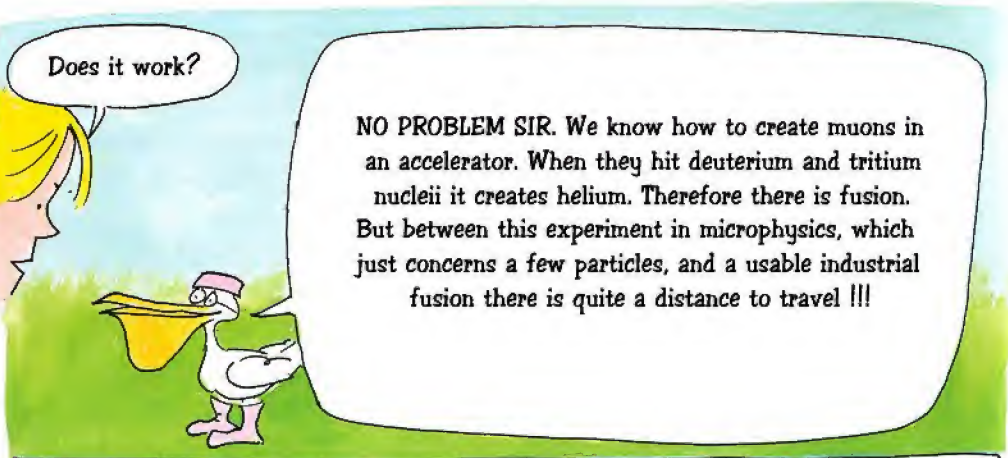
We can create complex chemical reactions in a cold gaseous mix by bombarding the molecules with electrons via a simple electrical discharge.



For example:
2CH4 (methane) + ϟ gives C2H2 (acetylene) +3H2

In a molecule we can replace the electrons with MUONS, particles which resemble big electrons and which bring the various nucleii closer together.




Does it work?
NO PROBLEM SIR. We know how to create muons in an accelerator. When they hit deuterium and tritium nucleii it creates helium. Therefore there is fusion. But between this experiment in microphysics, which just concerns a few particles, and a usable industrial fusion there is quite a distance to travel !!!


We could also play with the SPINS of nucleii. That is to say make them dance a waltz instead of a tango. It improves the efficacity of the collisions.
The Moon too pale, dressed with a pearl


BANG
Oh sorry!
...Can't you be careful !


There you are, it's the same story all over again
N


Everything isn't quite worked out yet in nuclear physics
Future discoveries could change everything


All this is just beginning. What do you think Archibald?

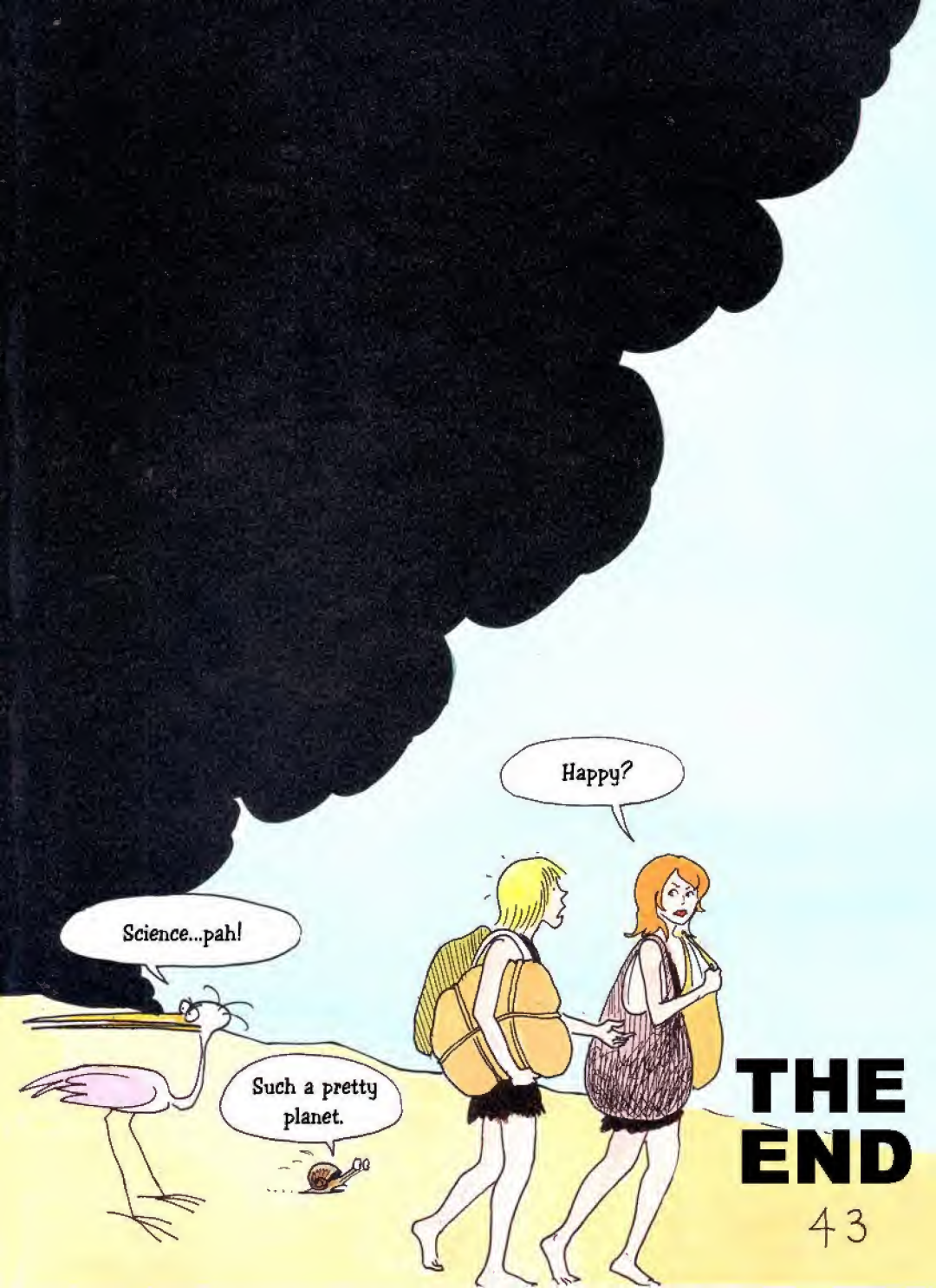

Nuclear is BOTH an immense hope AND a terrible menace.


Yes I'm listening...


I'm the best !..
!...


YEAH !
NO !


I've always said that inventing FIRE was a great mistake...


Happy?
Science...pah!
Such a pretty planet.
THE END